Sensors and Instruments for Operation at Low Temperatures

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Overview

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General Considerations for operating in low temperatures

- Two possible low temperature surface environments
  - In vacuum (Icy Satellites, comets, shaded areas on Moon, etc.): radiative cooling
  - In Atmosphere (Titan, Mars): convective cooling
  - Temperature Regimes
    - The Moon (−230 C in the permanently shadowed regions and −180 C to 110 C cycles),
    - Mars (−120 C to 20 C cycles),
    - Titan (−145 C), and
    - Comets (−180 C)
- In both cases sensors and instruments need to be thermally isolated from spacecraft thermal radiation
  - Away from radiators or other heat sources that would warm the instrument or sensor
  - Requires thermal analysis, particularly of thermal paths through structural, power, or data interfaces to insure adequate isolation
- Any moving parts will require special attention, particularly those needing lubrication
- No heritage is available for extreme low temperatures: new systems will need extensive testing in relevant environment
  - Lifetime testing may be difficult to accomplish, depending on planned mission duration

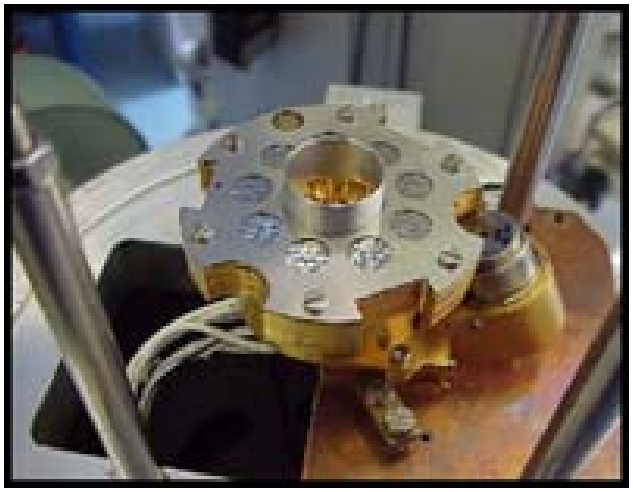
Sensor and Instrument – Integrated Circuits

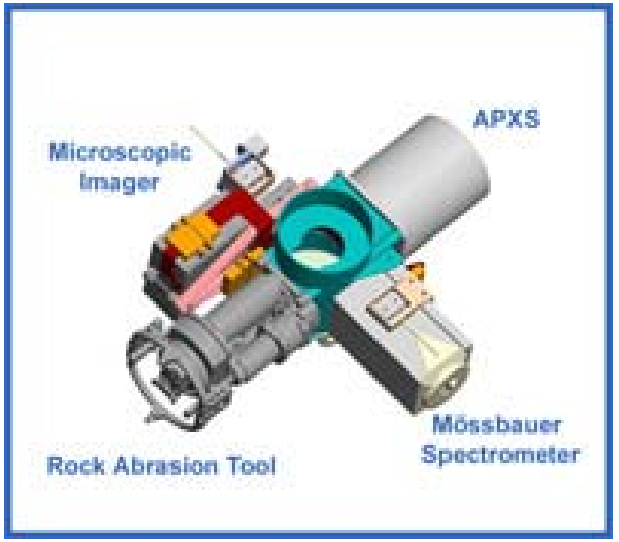
- The development of cold–temperature and wide–swing, low–temperature tolerant Si–based circuits calls for understanding of the following phenomena:
  - At temperatures below −150◦C, Si–based bipolar transistors suffer from carrier freeze– out. • Hot carrier injection accelerates the aging of MOSFETS as a function of reducing temperature.
- SiGe–based heterojunction bipolar transistors (HBT) do not suffer from this carrier freeze–out problem.
  - Further complication is combined effects of radiation and colder temperatures (such as the surface environment of Europa) on Si–based devices are not well understood.
- Packaging of devices for the temperature range of NASA's missions requires careful selection and evaluation of substrate, die attach, and passivation materials capable of operating at low temperatures without transitioning to a glass phase, forming excessive or brittle intermetallics, or breaking due to mismatched thermal expansion coefficients.
- More on this topic later

Contact Instruments

- MER has used contact instruments (Mossbauer, Alpha Particle X-Ray Spectrometer (APXS)) on rocks to determine mineralogy
  - Likely applicable directly to lunar or asteroid environments (although extreme low-g environments will require some sort of anchoring)
  - Not useful on icy materials – new techniques will be needed
  - Thermal difference between instrument and icy surface will need to be controlled to avoid “tongue on a cold lampost” effect (unless this is a desired outcome for something like a seismometer that requires solid sustained surface contact)
    - Also to avoid surface sublimation during analysis

MER Instruments

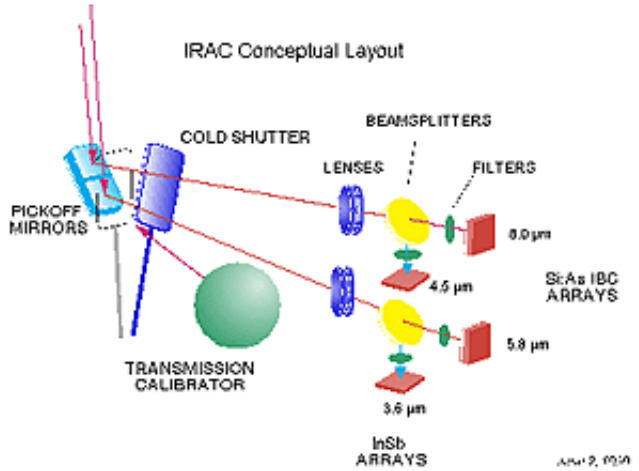


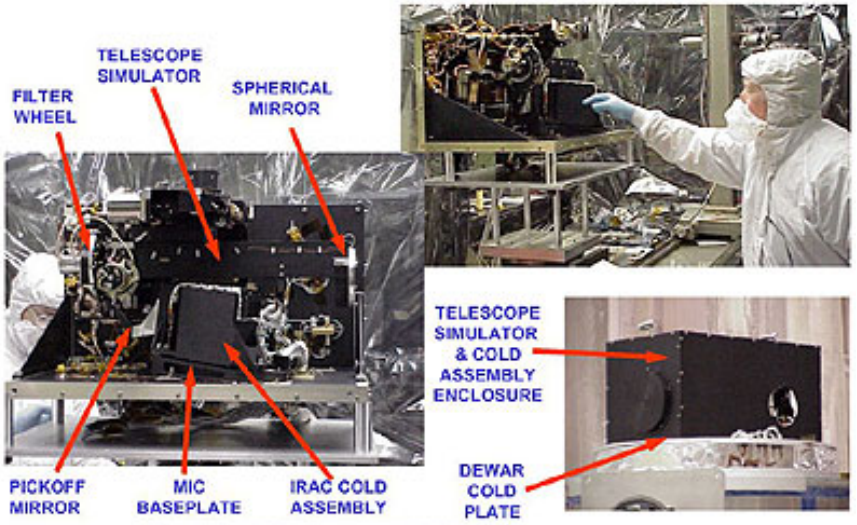


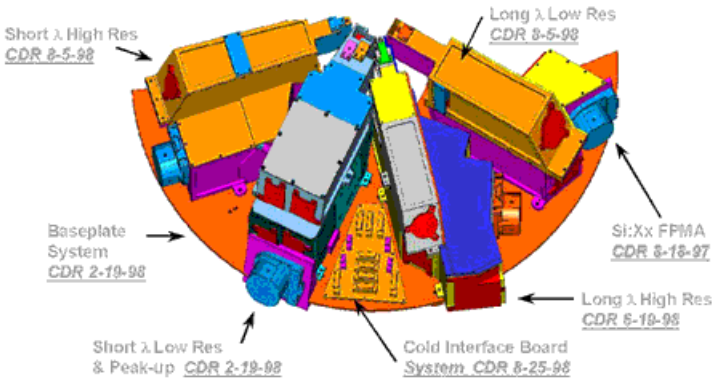
Imaging Arrays and Spectrometers

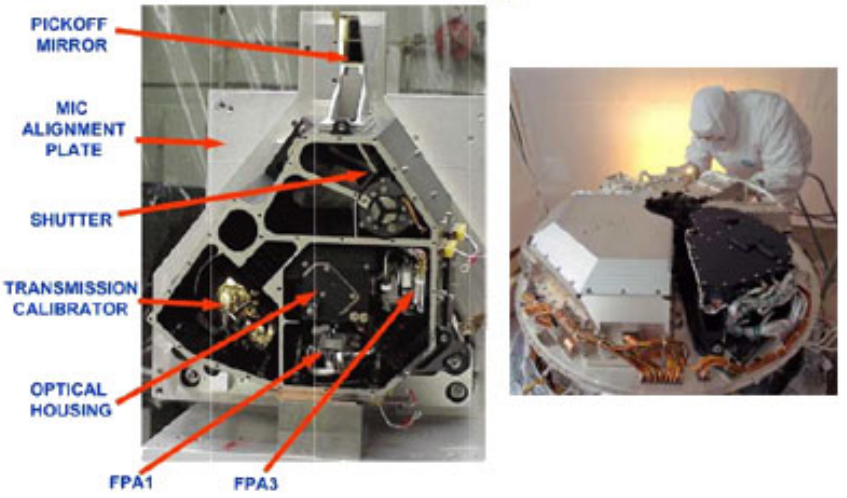
- Low temperature imaging systems have been built for infrared ranges (IRAS, Spitzer)
  - 256 X 256, 128 X 128, and 32 X 32 Arrays
  - Expensive and limited in spectrum
- MER Mini-TES may be applicable in some environments (spot spectrometer only)
- Current Mars Micro-imagers (MER, Phoenix) may be useful on Moon or Asteroid, but again may not be suitable for extreme LT and icy surfaces
- Science goals and environment limitations (reflected or emitted spectrum of target material) will dictate spectrum desired,
  - heritage systems may not be suitable, requiring completely new designs

Spitzer Infrared Array Camera and Spectrograph









Summary & Conclusions

- While some heritage exists, current sensors and instruments cannot be extended to all LT environments
- Need to determine what can be accomplished in the target environment (potential observables, material analyses) to focus sensor and instrument design on achievable science goals
- Test key components in LT environment as soon as possible to allow for alternatives/work-arounds
  - May require development of suitable target materials as well (comet, icy satellite surface material) to verify sensor/instrument can obtain the desired results

The End